MULTIBEAM OPTICAL SCANNING DEVICE

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SPECIFICATION

[TITLE OF THE INVENTION]

Multibeam optical scanning device

[ABSTRACT]

[Object] To realize a multibeam optical scanning device which can secure reliable and stable image reproducibility, by use of a light source unit using a plurality of general-purpose semiconductor lasers.

[Solution Means] In a multibeam optical scanning device of the present invention, a light source unit 400 comprises n semiconductor lasers (n≥2), n coupling lenses paired with the

n semiconductor lasers, and supporting members 103 and 103′ for symmetrically arranging the n semiconductor lasers and coupling lenses in the main scanning direction and supporting these as one body, a positional relationship of the respective semiconductor lasers and coupling lenses paired therewith is set so that all light beams emitted from the respective semiconductor lasers intersect, after passing through the first optical system 402, in the main scanning direction in the vicinity of a deflecting and reflecting surface of the deflector, and angles created by the optical axis of the first optical system and the respective light beams made incident into the deflector are set so as to satisfy "(Condition 1) where the beam spot diameter on the scanning surface around 25°C with a central image height is provided as ω_0, the range of fluctuations in the beam spot diameter on the scanning surface at the respective image heights within a range of 10-50°C is within a range of 25% of ω_0."

[WHAT IS CLAIMED IS;]

[Claim 1] A multibeam optical scanning device which converges, on a scanning surface, a plurality of light beams emitted from a multibeam light source unit by a scanning optical means including a first optical system, a deflector, and a second optical system and thereby carrying out scanning in the main

scanning direction, wherein

said multibeam light source unit comprises n semiconductor lasers ($n \geq 2$), n coupling lenses paired with the n semiconductor lasers, and supporting members for symmetrically arranging the n semiconductor lasers and coupling lenses in the main scanning direction and supporting these as one body, a positional relationship of the respective semiconductor lasers and coupling lenses paired therewith is set so that all light beams emitted from the respective semiconductor lasers intersect, after passing through the first optical system, in the main scanning direction in the vicinity of a deflecting and reflecting surface of the deflector, and angles created by the optical axis of the first optical system and the respective light beams made incident into the deflector are set so as to satisfy the following Condition 1.

(Condition 1) Where the beam spot diameter on the scanning surface around 25°C with a central image height is provided as ω_0, the range of fluctuations in the beam spot diameter on the scanning surface at the respective image heights within a range of 10-50°C is within a range of 25% of ω_0.

[Claim 2] A multibeam optical scanning device as set forth in Claim 1, wherein

a distance from the multibeam light source unit to the

deflector is set so that angles created by the optical axis of the first optical system and the respective light beams made incident into the deflector satisfy the above Condition 1.

[Claim 3] A multibeam optical scanning device as set forth in Claim 1, wherein

an arrangement distance between the respective semiconductor lasers is set so that angles created by the optical axis of the first optical system and the respective light beams made incident into the deflector satisfy the above Condition 1.

[Claim 4] A multibeam optical scanning device which converges, on a scanning surface, a plurality of light beams emitted from a multibeam light source unit by a scanning optical means including a first optical system, a deflector, and a second optical system and thereby carrying out scanning in the main scanning direction, wherein

said multibeam light source unit comprises n semiconductor lasers ($n \geq 2$), n coupling lenses paired with the n semiconductor lasers, and supporting members for symmetrically arranging the n semiconductor lasers and coupling lenses in the main scanning direction and supporting these as one body, a positional relationship of the respective semiconductor lasers and coupling lenses paired therewith is set so that all light beams emitted from the respective semiconductor lasers intersect,

after passing through the first optical system, in the main scanning direction in the vicinity of a deflecting and reflecting surface of the deflector, and a lateral image-forming magnification β_2 in the sub-scanning direction of the second optical system is set so as to satisfy the following Condition 1 (Claim 4).

(Condition 1) Where the beam spot diameter on the scanning surface around 25°C with a central image height is provided as ω_0, the range of fluctuations in the beam spot diameter on the scanning surface at the respective image heights within a range of 10-50°C is within a range of 25% of ω_0.

[Claim 5] A multibeam optical scanning device as set forth in any one of Claims 1 through 4, wherein

in addition to a first light source portion comprising n semiconductor lasers (n≥2), n coupling lenses paired with the n semiconductor lasers, and supporting members for symmetrically arranging the n semiconductor lasers and coupling lenses in the main scanning direction and supporting these as one body, said multibeam light source unit is provided with a second light source portion which comprises m semiconductor lasers (m≥2), m coupling lenses, and supporting members and is constructed similarly to the first light source portion, and a beam synthesizing means for emitting light beams from

said first and second light source portions in a manner approximated in the sub-scanning direction.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention]

The present invention relates to an optical scanning device to be used in a writing system of a recording apparatus such as a digital process copying machine, a laser printer, a laser facsimile, or a laser plotter, and in particular, it relates to a multibeam optical scanning device wherein recording rate has been remarkably improved by simultaneously scanning a scanning surface of a photosensitive body or the like with a plurality of light beams.

[0002]

[Prior Arts] As a means for improving the recording rate of an optical scanning device used in a weighting system of a recording apparatus such as a laser printer or a laser facsimile, there provided is a method for increasing the rotating speed of a rotating polygonal mirror (polygon mirror) as a deflecting means. However, in this method, motor durability, noise, vibration, and modulation speed of a semiconductor laser come into question and the recording rate is limited. Therefore, multibeam optical scanning devices have been offered, wherein

the recording rate has been improved by simultaneously recording a plurality of lines by scanning with a plurality of light beams at a time. Examples thereof include a method for synthesizing light beams from a plurality of semiconductor lasers by means of a beam splitter and, as disclosed in Japanese Unexamined Patent Publication No. Sho-56-42248, a method which uses a semiconductor laser array in that a plurality of light emitting portions have been disposed in an array shape. However, in the above semiconductor laser array, since a sensor to detect output is shared despite a plurality of light sources, light output feedback as in a normal semiconductor laser is impossible in real time. Nevertheless, since the light sources are close, output easily changes due to crosstalk thereof and the optical amount cannot be accurately controlled. In addition, the above semiconductor laser array has, because of its distinctiveness, a drawback of being expensive. In addition, these become more disadvantageous as the number of light emitting portions increases. In contrast thereto, although no such problems as described above exist in a method which uses a plurality of general-purpose semiconductor lasers and synthesizes light beams from the plurality of semiconductor lasers, an improvement in environmental stability and assembling characteristics is necessary.

[0003] Therefore, the present inventor has already solved these problems and thus offered novel multibeam light source units which emit a plurality of beams (Japanese Patent Application No. Hei-9-178479 and Japanese Patent Application No. Hei-10-106599). Examples of these previously applied multibeam light source units include a construction comprising a first light source portion including a plurality of semiconductor lasers, coupling lenses provided in pairs with these semiconductor lasers, and a supporting member for arranging the plurality of semiconductor lasers and coupling lenses disposed in the main scanning direction and supporting these as one body, a second light source portion constructed similarly to the first light source portion, and a beam synthesizing means for emitting light beams from the first and second light source portions in an approximated manner in the sub-scanning direction.

[0004]

[Problems to be Solved by the Invention] In a case where a polygon mirror is used as a deflector, since the center of rotation of the polygon mirror is set out of alignment with the optical axis of a second optical system (scanning optical system), with the beam deflection, a reflecting point on a deflecting and reflecting surface is displaced, and an "optical

sag" in that the starting point of deflection of a deflected light flux changes occurs. And if this "optical sag" exists, a light flux follows different courses between the plus image-height side and minus image-height side with respect to the optical axis of the scanning optical system. Accordingly, the amount of curvature of field particularly in the sub-scanning direction greatly changes according to the image height. It is possible to reduce the influence of this "optical sag" in design of the scanning optical system, however, when a single beam is developed into a multibeam, leaving aside a case where a semiconductor laser array is used as a multibeam light source unit, in the case where a light source unit comprising "a plurality of semiconductor lasers, coupling lenses provided in pairs with these semiconductor lasers, and a supporting member for arranging the plurality of semiconductor lasers and coupling lenses disposed in the main scanning direction and supporting these as one body" as priorly offered by the present applicant is used, influence of an "optical sag" by reason of the semiconductor lasers' arrangement in the main scanning direction is inevitable.

[0005] For example, in a case where a light source unit of a 2-beam method by means of two semiconductor lasers is considered, even if a scanning optical system is designed so

as to reduce the influence of an "optical sag" on a light beam from one semiconductor laser, this increases the influence of an "optical sag" on the light beam from the other semiconductor laser rather than reducing it. And, a change in the amount of curvature of field according to each image height is expressed as a shift of the beam waist position with respect to a scanning surface. This develops unevenness in the beam spot diameter according to each image height and considerably deteriorates image reproducibility.

[0006] The present invention has been made in view of the above-described circumstances and an object thereof is to realize a multibeam optical scanning device which can secure reliable and stable image reproducibility, by use of a multibeam light source unit using a plurality of general-purpose semiconductor lasers.

[0007]

[Means for Solving Problems] A multibeam optical scanning device of the present invention is "a multibeam optical scanning device which converges, on a scanning surface, a plurality of light beams emitted from a multibeam light source unit by a scanning optical means including a first optical system, a deflector, and a second optical system and thereby carrying out scanning in the main scanning direction," and has the following

characteristics (Claim 1). Namely, in the multibeam optical scanning device, the multibeam light source unit comprises n semiconductor lasers (n≥2), n coupling lenses paired with the n semiconductor lasers, and supporting members for symmetrically arranging the n semiconductor lasers and coupling lenses in the main scanning direction and supporting these as one body. At this time, a positional relationship of the respective semiconductor lasers and coupling lenses paired therewith is set so that "all light beams emitted from the respective semiconductor lasers intersect, after passing through the first optical system, in the main scanning direction in the vicinity of a deflecting and reflecting surface of the deflector," and angles created by the optical axis of the first optical system and the respective light beams made incident into the deflector are set so as to satisfy "(Condition 1) where the beam spot diameter on the scanning surface around 25°C with a central image height is provided as ω_0, the range of fluctuations in the beam spot diameter on the scanning surface at the respective image heights within a range of 10-50°C is within a range of 25% of ω_0."

[0008] In addition, the multibeam optical scanning device as set forth in Claim 1 is characterized in that "a distance from the multibeam light source unit to the deflector" is set

so that angles created by the optical axis of the first optical system and the respective light beams made incident into the deflector satisfy the above Condition 1 (Claim 2). Alternatively, the multibeam optical scanning device as set forth in Claim 1 is characterized in that "an arrangement distance between the respective semiconductor lasers" is set so that angles created by the optical axis of the first optical system and the respective light beams made incident into the deflector satisfy the above Condition 1 (Claim 3). Furthermore, a multibeam optical scanning device as another mode is characterized in that "a lateral image-forming magnification β_2 in the sub-scanning direction of the second optical system" is set so as to satisfy the above Condition 1.

[0009] Moreover, the multibeam optical scanning device as set forth in any one of Claims 1 through 4 is characterized in that the multibeam light source unit "is provided with: in addition to a first light source portion comprising n semiconductor lasers ($n \geq 2$), n coupling lenses paired with the n semiconductor lasers, and supporting members for symmetrically arranging the n semiconductor lasers and coupling lenses in the main scanning direction and supporting these as one body; a second light source portion which comprises m semiconductor lasers ($m \geq 2$), m coupling lenses, and supporting

members and is constructed similarly to the first light source portion; and a beam synthesizing means for emitting light beams from the first and second light source portions in a manner approximated in the sub-scanning direction" (Claim 5).

[0010]

[Modes for carrying out the Invention] Hereinafter, constructions, operations, and actions of the present invention will be described in detail with reference to the drawings. Fig. 1 shows, as a mode for carrying out the present invention, a schematic construction of a multibeam optical scanning device with a multibeam light source unit loaded. In Fig. 1, a light source unit 400: includes a first light source portion 401-1 in which two general-purpose semiconductor lasers 101 and 102 and two coupling lenses (unillustrated) paired with the two semiconductor lasers 101 and 102 are symmetrically arranged in the main scanning direction and are supported by a supporting member 103 as one body, and a second light source portion 401-2 in which, similarly, two general-purpose semiconductor lasers 106 and 107 and two coupling lenses (unillustrated) paired with the two semiconductor lasers 106 and 107 are symmetrically arranged in the main scanning direction and are supported by a supporting member 103′ as one body; is formed by disposing the first light source portion 401-1 and second light source

portion 401-2 in the sub-scanning direction and fitting and fixing the same to a holder 401; and emits four light beams by use of a total of four semiconductor lasers. Herein, details of the light source unit will be described later.

[0011] Four light beams emitted from the light source unit 400 are light beams radiated from the individually modulatable four semiconductor lasers and respectively coupled by the coupling lenses, and after intersecting in the main scanning direction in the vicinity of a deflecting and reflecting surface of a polygon mirror 403 as a deflector through a cylindrical lens 402 as a first optical system, the light beams are deflected and scanned by the polygon mirror 403, and after passing through a lens composed of two lenses (for example, an f-θ lens) 404, the light beams are reflected, by a turning mirror 405, against a photosurface 407a of a photoconductive photosensitive body 407, which is an entity of a scanning surface, and are focused, by a lens (for example, a troidal lens) 406, onto the photosurface 407a. By four beam spots, four scanning lines adjacent with an appointed pitch in the sub-scanning direction are simultaneously scanned in the main scanning direction S, thus image recording is carried out.

[0012] Moreover, the lenses 404 and 406 disposed between the polygon mirror 403 and photosurface (scanning surface) 407a

compose a second optical system (a scanning optical system), and a scanning optical means includes the first optical system 402, the deflector 403, and the second optical system 404 and 406. In addition, a synchronous detection mirror 408 is arranged outside an imaging region of the turning mirror 405, and a light beam reflected by this mirror 408 is detected by a synchronous detection sensor 409. This synchronous detection sensor 409 issues a synchronous detection signal upon detection of the light beam, and based on this synchronous detection signal, timing of writing start is judged. On the other hand, output from the synchronous detection sensor 409 is sent to a pitch operating portion (unillustrated). This pitch operating portion computes intervals between four light beams in the sub-scanning direction, calculates a pitch correcting amount to correct the scanning line pitch based thereon, and sends the same to a control portion (unillustrated). The control portion controls, according to the pitch correcting amount, a diving means such as a motor (unillustrated) and thereby displaces a holder 410 of the light source unit 400 by a rotation around the optical axis by a minute amount and adjusts the posture of the light source unit 400 so that a desirable scanning line pitch is obtained on the scanning surface.

[0013] Now, Fig. 2 is an exploded perceptive view showing

a construction example of light source portions of the light source unit 400 to be loaded into the multibeam optical scanning device as shown in Fig. 1, which shows a construction example of a 4-beam light source unit which uses four semiconductor lasers in total. In Fig. 2, semiconductor lasers 101 and 102 are supported by being respectively press-fitted into fitting holes (unillustrated) formed on the rear side of a supporting member 103 made of die-cast aluminum, in a line with an appointed distance in the main scanning direction. In addition, coupling lenses 104 and 105 are fixed by filling a UV curing adhesive or the like between the semiconductor lasers 101 and 102 and U-shaped supporting portions 103-1 and 103-2 formed in pairs, in a manner where the X-position in the optical axis direction is aligned so that divergent light fluxes of the respective semiconductor lasers 101 and 102 result in a desirable light flux condition (in the present mode, parallel light fluxes) and the Y and Z positions are aligned so that the beam emitting direction results in an appointed beam emitting direction. Then, this portion composed of two semiconductor lasers 101 and 102 and coupling lenses 104 and 105 supported by the supporting member 103 is referred to as a first light source portion 401-1. In addition, the semiconductor lasers 101 and 102 and the coupling lenses 104 and 105 are nearly symmetrically

arranged with respect to a center of symmetry a_1.

[0014] A similar construction is provided for a second light source portion 401-2, as well, wherein semiconductor lasers 106 and 107 are supported by being respectively press-fitted into fitting holes (unillustrated) formed on the rear side of a supporting member 103' made of die-cast aluminum, in a line with an appointed distance in the main scanning direction. In addition, coupling lenses 108 and 109 are fixed by filling a UV curing adhesive or the like between the semiconductor lasers 106 and 107 and U-shaped supporting portions formed in pairs, in a manner where the X-position in the optical axis direction is aligned so that divergent light fluxes of the respective semiconductor lasers 101 and 102 result in a desirable light flux condition (in the present mode, parallel light fluxes) and the Y and Z positions are aligned so that the beam emitting direction results in an appointed beam emitting direction. In addition, the two semiconductor lasers 106 and 107 and the coupling lenses 108 and 109 are nearly symmetrically arranged with respect to a center of symmetry a_2.

[0015] In addition, a symbol 111 denotes a prism as a beam synthesizing means, and this prism 111 includes a 1/2-wave plate 112, a polarization split film 111-1, and a reflecting surface 111-2 and functions so as to emit beams from the second light

source portion 401-2 in a manner approximated in the sub-scanning direction to beams from the first light source portion 401-1. Namely, the semiconductor lasers 101 and 102 provided in the first light source portion 401-1 have been set so that the polarizing state of light beams radiated from these semiconductor lasers becomes, for example, approximately a P-polarization against the polarization split film 111-1. Therefore, light beams from the semiconductor lasers 101 and 102 penetrate through the polarization split film 111-1 of the prism 111 after being collimated by the coupling lenses 104 and 105. The semiconductor lasers 106 and 107 provided in the second light source portion 401-2 have been set so that the polarizing state of light beams radiated from these semiconductor lasers becomes, for example, approximately a P-polarization against the polarization split film 111-1. Therefore, when light beams from the semiconductor lasers 106 and 107 penetrate through the 1/2-wave plate 112 after being collimated by the coupling lenses 108 and 109, planes of polarization are turned by 90 degrees and the light beams result in an S-polarization against the polarization split film 111-1, and the light beams are reflected by the reflecting surface 111-2 of the prism 111, are then reflected by the polarization split film 111-1, and are emitted from the prism 111. As such,

the four light beams radiated from the four semiconductor lasers 101, 102, 106, and 107 and collimated by the corresponding coupling lenses 104, 105, 108, and 109 are emitted from the prism 111 in a manner mutually approximated in the sub-scanning direction. The first light source portion 401-1, the second light source portion 401-2, and the prism 111 are fitted and fixed to a holder 410 of the light source unit 400 as shown in Fig. 1.

[0016] Furthermore, the multibeam light source unit 400 as shown in Fig. 1 is not limited to the construction of Fig. 2, and various constructions can be considered, such as a construction where four semiconductor lasers 501, 502, 503, and 504 and coupling lenses 505, 506, 507, and 508 are arranged in the main scanning direction nearly symmetrically with respect to a center of symmetry a_1 and supported by one supporting member 509, as in another construction example of a 4-beam light source unit shown in Fig. 3, or as a construction of the simplest multibeam light source unit, a construction of only the first light source portion of Fig. 2 where two semiconductor lasers 201 and 202 and coupling lenses 204 and 205 are arranged in the main scanning direction nearly symmetrically with respect to a center of symmetry a_1 and supported by a supporting member 203, as in a construction example of a 2-beam light source unit

as shown in Fig. 4. In addition, in constructions of Fig. 3 and Fig. 4, since no beam synthesizing prism is used, a reduction in size and weight and a reduction in cost of the light source unit can be realized.

[0017] In the above, construction examples of a multibeam optical scanning device and a multibeam light source unit to be loaded into the same optical scanning device have been described. In the present invention, in addition to the above construction, a positional relationship between the respective semiconductor lasers of the light source unit 400 and the coupling lenses paired therewith is set so that "all light beams emitted from the respective semiconductor lasers intersect, after passing through the first optical system 402, in the main scanning direction in the vicinity of the deflecting and reflecting surface of the deflector 403," and the angles created between the optical axis of the first optical system 402 and the respective light beams made incident into the deflector 403 are set so as to satisfy "(Condition 1) where the beam spot diameter on a scanning surface around 25°C with a central image height is ω_0, the range of fluctuations in the beam spot diameter on the scanning surface at the respective image heights within a range of 10-50°C is within a range of 25% of ω_0." In addition, in the present invention, in addition to the above construction,

"the distance from the multibeam light source unit 400 to the deflectors 403" is set so that the angles created between the optical axis of the first optical system 402 and the respective light beams made incident into the deflectors 403 satisfy the above Condition 1, or "the arrangement distance between the respective lasers" is set so that the angles created between the optical axis of the first optical system 402 and the respective light beams made incident into the deflectors 403 satisfy the above Condition 1. Furthermore, as another mode, "lateral image-forming magnification β_2 in the sub-scanning direction of the second optical system 404 and 406" is set so as to satisfy the above Condition 1. In the following, detailed embodiments of the present invention will be described.

[0018] (Embodiment 1: corresponding to Claims 1, 2, and 3) The present embodiment is a concrete example of a multibeam optical scanning device in a case where the 2-beam light source unit as shown in Fig. 4 is used as a light source unit 400 in a multibeam optical scanning device of the construction as shown in Fig. 1. Fig. 5 shows a construction when the light source unit of Fig. 4 is viewed from the Z-direction. Respective positional relationships of the respective semiconductor lasers 201 and 202 and the coupling lenses disposed in pairs therewith are set so that all light beams intersect in the main

scanning direction in the vicinity of the deflecting and reflecting surface of the deflector 403 after passing through a cylindrical lens 402 as the first optical system (Fig. 1). Herein, as a concrete example, Fig. 5(a) is an example, wherein with respect to the optical axes of the two coupling lenses 204 and 205, the positions of light emitting points of the respective semiconductor lasers 201 and 202 are shifted to the outside by δ_{201} and δ_{202} to make the arrangement distance d between the semiconductor lasers 201 and 202 wider than the distance between optical axes of the coupling lenses 204 and 205, so that two light beams penetrated through the coupling lenses 204 and 205 proceed in intersecting directions and intersect, after passing through the cylindrical lens 402, in the main scanning direction in the vicinity of the deflecting and reflecting surface of the deflector 403. Moreover, Fig. 5(b) is an example, wherein the two semiconductor lasers 201 and 202 and the coupling lenses 204 and 205 disposed in pairs therewith are arranged with their optical axes inclined, the angle created by the two optical axes is provided as ϕ, and this angle ϕ is adjusted, so that two light beams penetrated through the coupling lenses 204 and 205 intersect, after passing through the cylindrical lens 402, in the main scanning direction in the vicinity of the deflecting and reflecting surface of

the deflector 403.

[0019] Now, Figs. 6 are views showing optical systems from light sources to a scanning surface and optical paths of light beams passing therethrough in an extended manner on a plane in the main scanning direction, wherein (a) is an example where light beams from two semiconductor lasers 201 and 202 do not intersect in the vicinity of a deflecting and reflecting surface of a deflector 403, and (b) is an example where light beams from two semiconductor lasers 201 and 202 intersect, after passing through a first optical system (unillustrated) in the main scanning direction in the vicinity of a deflecting and reflecting surface of a deflector. In Fig. 6(a), D_1 denotes a reflecting surface of the polygon mirror 403 when a light beam emitted from the semiconductor laser 201 reaches a certain image height at the scanning surface 407, and D_2 denotes a reflecting surface of the polygon mirror 403 when a light beam emitted from the semiconductor laser 202 reaches the same image height at the scanning surface 407. The respective light beams are separated with a certain angle $\Delta\alpha_{201}+\Delta\alpha_{202}$ ($\Delta\alpha_i$ is an angle created between a light beam emitted from a semiconductor laser of symbol i, to be made incident into a deflector and the optical axis of a first optical system (unillustrated)) when the light beams are made incident into the polygon mirror 403.

Accordingly, in proportion to this angle difference, a time lag occurs between reflecting surfaces (such as a difference between D_1 and D_2) to reach the same image height.

[0020] In a case of Fig. 6(a), the two light beams pass through considerably different optical paths, whereas in a case of Fig. 6(b), the light beams pass through completely identical optical paths. As in Fig. 6(a), when light beams pass through different positions of the respective optical elements, the light beams as a matter of course receive different optical effects. Accordingly, optical characteristics such as aberrations of the two light beams that reach an identical image height in the main scanning direction on the scanning surface are different, and this has a great influence in particular on fluctuations in scanning line pitches between image heights. Therefore, in the present embodiment, as in Fig. 6(b), by intersecting two light beams in the vicinity of the reflecting surface of the polygon mirror 403, the positions of incidence into the reflecting surface are coordinated (for example, so as to make two light beams simultaneously incident into the reflecting surface at the D_1' position), so that the light beams follow almost identical paths in the main scanning direction of the optical elements to reach an identical image height in the main scanning direction on the scanning surface, whereby a

fluctuation in scanning line pitches between image heights is effectively decreased.

[0021] As such, as configurational relationships between the semiconductor lasers and coupling lenses constructed so that respective light beams intersect in the main scanning direction in the vicinity of a deflecting and reflecting surface of a deflector, two types of Fig. 5(a) and Fig. 5(b) can be considered as mentioned above. Fig. 5(a) is a method wherein light emitting points of the semiconductor lasers 201 and 202 are shifted from the optical axes of the respective coupling lenses 204 and 205 in the main scanning direction. However, if the shifting amounts δ_{201} and δ_{202} in the main scanning direction become great, the light beams pass through the peripheral portions of the coupling lenses 204 and 205, consequently, an occurrence of wave aberration becomes considerable. Such an increase in wave aberration widens the beam spot diameter on the scanning surface, causing a significant decline in image reproducibility. For avoidance thereof, a method can be considered, wherein, as shown in Fig. 5(b), the respective coupling lenses 204 ad 205 are arranged so that the angle created by their own optical axes becomes ϕ, and the respective semiconductor lasers 201 and 202 are disposed on the optical axes of the coupling lenses paired therewith in the main scanning

direction.

[0022] Herein, in terms of the light source unit set as such, Fig. 7(a) and Fig. 7(b) show a curvature of field on the scanning surface. Incidentally, Fig. 7(c) shows a curvature of field in a single-beam state where semiconductor lasers are arranged on the optical axis of the first optical system 402, as a reference. As can be judged from this diagram, design is provided so that imaging performance of the second optical system (lens 404 and lens 406 of Fig. 1) becomes optimum when semiconductor lasers are arranged on the optical axis of the first optical system 402. Nevertheless, in the light source unit as shown in Fig. 4, the semiconductor lasers 201 and 202 are separated in the main scanning direction. Therefore, as shown in Fig. 6, when light beams are made incident into the deflector 403, the light beams acquire an angle $\Delta\alpha_{201}$ or $\Delta\alpha_{202}$, respectively. As a result, curvature of field in the sub-scanning direction is inclined as in Fig. 7(a) and Fig. 7(b). The reason that inclining directions of the curvature of field in the sub-scanning direction are opposite in Fig. 7(a) and Fig. 7(b) is because the respective semiconductor lasers are arranged nearly symmetrical with respect to the optical axis of the first optical system. And, it is extremely difficult to reduce the influence of an "optical sag" due to this angle by design of lens shapes,

etc.

[0023] Such an inclination of the curvature of field is expressed as a shift of the beam waist position with respect to the scanning surface, which is shown in Fig. 8. Fig. 8(a) shows "depth curves of the beam spot diameter (fluctuations in the beam spot diameter with respect to light spot defocusing)" of a light spot of the semiconductor laser 201 (202) according to each image height in the sub-scanning direction, while in Fig. 8(b), shown are "depth curves of the beam spot diameter (fluctuations in the spot diameter with respect to light spot defocusing)" of a light spot according to each image height in the sub-scanning direction in a single-beam state where semiconductor lasers are arranged on the optical axis of the first optical system, as a reference. The depth curves of the beam spot diameter at each image height are extremely well-matched at this time. However, if curvature of field in the sub-scanning direction is inclined as shown in Fig. 7(a) and Fig. 7(b), since the beam waist position is shifted with respect to the scanning surface, depth curves of the beam spot diameter have unevenness according to each image height as shown in Fig. 8(a). Due to this unevenness, tolerance of a component attaching errors and environmental changes that inevitably occur becomes narrow, thus it becomes difficult to maintain

the beam spot diameter at a constant diameter at all times.

[0024] Herein, when image reproducibility is brought into question, a discussion regarding to what extent the beam waist position is shifted, namely, to what extent the curvature of field is inclined, is not very essential. What comes into a question is that to what extent the target spot diameter is uneven, and to what extent the beam spot diameter changes according to the component attaching errors and environmental changes. In general, an environmental change often means an actual change in outside air-temperature from 10°C to 35°C or from 10°C to 40°C. However, the scanning optical means, etc., which exerts influence on the beam spot diameter is provided inside a machine, and accordingly, temperature slightly rises (by approximately 10°C-15°C) compared to the outside air-temperature. Therefore, in the present specification, an environmental change is provided as from 10°C to 50°C.

[0025] In addition, an experiment for image evaluation by the present inventor, et al. has revealed that, in order to make a deterioration in image reproducibility be visually beyond recognition, where the target beam spot diameter is provided as ω_0, it is sufficient to suppress the range of fluctuations in the beam spot diameter within a range of 25% of ω_0. For example, where a target beam spot diameter is 27μm, if the range

of fluctuations thereof is suppressed within 27x0.25=6.75μm, a deterioration in image reproducibility cannot be visually recognized. Herein, the "target beam spot diameter" is defined as "a beam spot diameter on the scanning surface around 25°C with a central image height."

[0026] The reason that the beam spot diameter is uneven according to each image height compared to that of a single beam is because, since the semiconductor laser 201 and semiconductor laser 202 are separated in the main scanning direction, when light beams are made incident into the deflector 403, the respective light beams acquire an angle $\Delta\alpha_{201}$ or $\Delta\alpha_{201}$ with respect to the optical axis of the first optical system 402. Therefore, in the present invention, by setting this angle to "(Condition 1) where the beam spot diameter on a scanning surface around 25°C with a central image height is ω_0, the range of fluctuations in the beam spot diameter on the scanning surface at the respective image heights within a range of 10-50°C is within a range of 25% of ω_0," unevenness in the beam spot diameter including an environmental change is suppressed, thereby a deterioration in image reproducibility is reduced.

[0027] Concretely, the simplest method to decrease $\Delta\alpha_{201}$ and $\Delta\alpha_{202}$ so as to satisfy the (Condition 1) is to set the optical path from the light source unit to the deflector to an optimum

length. In an optical scanning device of the construction as shown in Fig. 1, when the distance from the light source unit 400 to the deflector 403 is provided as 276mm, curvatures of field in the sub-scanning direction are as in Fig. 7(a) and Fig. 7(b). Therefore, by extending the distance (concretely, the distance from the light source unit 400 to the first optical system 402) by 500mm further, inclination of the curvature of field is reduced as shown in Fig. 7(d), thus unevenness in the beam spot diameter can be reduced.

[0028] However, according to this method, the distance from the light source unit to the deflector is lengthened, the optical scanning device itself tends to increase in size. Accordingly, depending on the request in layout, this method cannot be used. Moreover, a change in this distance results in an increase in height in the sub-scanning direction of the light beam that penetrates through the optical elements (the lens 404 and lens 406 of Fig. 1) of the second optical system (the height becomes as indicated by the solid line of Fig. 9, and with 276mm, the height becomes as indicated by the dotted line), thereby causing a fluctuation in scanning line pitches between image heights.

[0029] In order to decrease $\Delta\alpha_{201}$ and $\Delta\alpha_{202}$ so as to satisfy the (Condition 1) without changing this distance, it is sufficient to set the distance d between the semiconductor laser

201 and semiconductor laser 202 to an optimum distance. In an optical scanning device having the structure shown in Fig. 1, curvatures of field in the sub-scanning direction when the distance d between the semiconductor laser 201 and semiconductor laser 202 is provided as 13mm are as in Fig. 7(a) and Fig. 7(b). Herein, if this distance d is shortened to 7mm, inclination of the curvature of field in the sub-scanning direction is decreased as shown in Fig. 7(e), thus unevenness in the beam spot diameter can be reduced.

[0030] (Embodiment 2: corresponding to Claims 1 and 4) The second method described in Embodiment 1, namely, the method wherein the distance between semiconductor lasers is changed can achieve a reduction in size of the light source unit, as well. However, currently, the beam spot diameter is in a decreasing trend due to the recent tendency toward high density and high quality. For achievement of a reduction in the beam spot diameter, an increase in the numerical aperture of light beams made incident into the deflector is required, therefore, the outside diameter of the coupling lenses also must be increased. Accordingly, a limit in approaching the distance between the semiconductor lasers inevitably occurs.

[0031] If the angle of incidence of the light beams into the deflector cannot be decreased by the methods as in Embodiment

1, in order to reduce the influence of an optical sag on the scanning surface, it is sufficient to set the lateral image-forming magnification β_2 of the second optical system from the deflector to the scanning surface to an optimum magnification. In an optical scanning device of the construction as shown in Fig. 1, curvatures of field in the sub-scanning direction where the lateral image-forming magnification β_2 in the sub-scanning direction of the second optical system disposed between the deflector 403 and the scanning surface (concretely, a photosurface of a photosensitive body) 407a are provided as

$|\beta_2| = 1.1$

are as shown in Fig. 7(a) and Fig. 7(b). Thereupon, if the lateral image-forming magnification in the sub-scanning direction of the second optical system is brought into a contracting tendency as in

$|\beta_2| = 0.7,$

inclination of the curvature of field in the sub-scanning direction is decreased as shown in Fig. 7(f), whereby unevenness in the beam spot diameter can be reduced. By setting the lateral image-forming magnification β_2 in the sub-scanning direction of the second optical system to an optimum magnification as in the above, it becomes possible to suppress the influence

of an optical sag on the scanning surface even if the angle of incidence of the light beams into the deflector is great to some degree.

[0032] (Embodiment 3: corresponding to Claims 1-4) The present embodiment is a concrete example of a multibeam optical scanning device in a case where the 4-beam light source unit as shown in Fig. 3 is used as a light source unit 400 in a multibeam optical scanning device of the construction as shown in Fig. 1. Fig. 10 shows a construction when the light source unit of Fig. 3 is viewed from the Z-direction. Respective positional relationships of the respective semiconductor lasers 501-504 and the coupling lenses 505-508 disposed in pairs therewith are set so that all light beams intersect in the main scanning direction in the vicinity of the deflecting and reflecting surface of the deflector 403 after passing through a cylindrical lens 402 as the first optical system (Fig. 1).

As a configurational relationship of the semiconductor lasers 501-504 and the coupling lenses 505-508, similar to Embodiment 1, two types can be considered, such as a method (Fig. 10(a)) wherein light emitting points of the respective semiconductor lasers 501-504 are shifted from the optical axes of the respective coupling lenses 505-508 in the main scanning direction by appointed shifting amounts δ_1 and δ_4, and a method

Fig. 10(b) wherein the respective coupling lenses 505-508 are arranged so that their respective optical axes form angles ϕ_{12}, ϕ_{23}, and ϕ_{34}, and the respective semiconductor lasers 501-504 are disposed on the optical axes of the coupling lenses 505-508 paired therewith in the main scanning direction.

[0033] In terms of the light source unit set as such, curvatures of field of the semiconductor lasers 501 and 504 on the scanning surface have greater inclinations compared to those of Fig. 7(a) and Fig. 7(b), which correspond to curvatures of field of the semiconductor lasers 502 and 503. For decreasing these inclinations and thereby reducing the unevenness of the beam waist position, it is sufficient to, as described in Embodiment 1, set the optical path length from the light source unit to the deflector 403 to an optimum length, and to decrease the angles $\Delta\alpha_{501}$, $\Delta\alpha_{502}$, $\Delta\alpha_{503}$, and $\Delta\alpha_{504}$ formed by the light beams emitted from the respective semiconductor lasers 501-504, to be made incident into the deflector 403 and the optical axis of the first optical system 402 so as to satisfy the aforementioned (Condition 1). However, by this method, the situation in that the distance from the light source unit to the deflector becomes long does not change from Embodiment 1 at all, and moreover, the more the semiconductor lasers are arranged in the main scanning direction in addition to the four

semiconductor lasers, the greater the angles of incidence of the light beams to the deflector become, consequently, the distance from the light source unit to the deflector set for a reduction thereof rapidly increases.

[0034] Therefore, by setting the distance d between the semiconductor lasers 501-504 to an optimum distance, it becomes possible to decrease $\Delta\alpha_{501}$ - $\Delta\alpha_{504}$ so as to satisfy the (Condition 1) without changing the distance from the light source unit to the deflector. However, for achievement of a reduction in the beam spot diameter, an increase in the numerical aperture of light beams made incident into the deflector is required, therefore, the outside diameter of the coupling lenses 505-508 also must be increased. Accordingly, a limit in approaching the distance between the semiconductor lasers inevitably occurs. Therefore, if the angle of incidence of the light beams into the deflector cannot be decreased by the above method, in order to reduce the influence of an optical sag on the scanning surface, it is sufficient to set the lateral image-forming magnification β_2 in the sub-scanning direction of the second optical system (lens 404 and lens 406 of Fig. 1) arranged between a section from the deflector 403 to the scanning surface 407, similar to Embodiment 2.

[0035] (Embodiment 4: corresponding to Claim 5) The present

embodiment is a concrete example of a multibeam optical scanning device in a case where the 4-beam light source unit as shown in Fig. 2 is used as a light source unit 400 in a multibeam optical scanning device of the construction as shown in Fig. 1. In the present embodiment, as a multibeam light source unit, two light source portions (Figs. 4 and 5) as described in Embodiment 1 or Embodiment 2 are prepared, while these are respectively referred to as a first light source portion 401-1 and a second light source portion 401-2, and provided is a beam synthesizing means (a beam synthesizing prism) 111 to emit light beams from these light source portions in a manner approximated in the sub-scanning direction. Since detailed contents of the present embodiment (to reduce a shift in the beam waist position between the respective image heights by the methods described in Claims 1 through 4) are similar to those of Embodiment 1 or Embodiment 2, a description thereof is omitted here.

[0036] (Embodiment 5) The above Embodiment 4 concerns a light source unit using four general-purpose semiconductor lasers. However, the number of semiconductor lasers that compose the light source unit does not cause any change in the aspect concerning the principles, and by the methods described in Claims 1 through 4, it is possible to reduce a shift in the beam waist position between the respective image heights. For example,

as a multibeam light source unit, a construction may be employed, wherein two 4-beam light source units having the construction as shown in Fig. 3 are prepared, while these are respectively referred to as a first light source portion and a second light source portion, and provided is a light beam synthesizing means for emitting light beams therefrom in a manner approximated in the sub-scanning direction, and by the methods as described in Claims 1 through 4, it is also possible to realize an 8-beam optical scanning device in that a shift in the beam waist position between respective image heights is reduced. In addition, the number of semiconductor lasers and coupling lenses arranged in the main scanning direction are not limited to an even number but may be an odd number such as three or five, and in this case, it is sufficient to align the optical axis of a semiconductor laser and a coupling lens located at the center in the main scanning direction with the optical axis of the first optical system, and for semiconductor lasers and coupling lenses arranged on both sides thereof, it is sufficient to carry out an adjustment by methods similar to those of Embodiment 1 or Embodiment 2.

[0037]

[Effects of the Invention] As has been described in the above, according to the invention as described in Claim 1, 2, 3, or

4, by decreasing the inclination of the curvature of field in the sub-scanning direction due to an optical sag and reducing a shift in the beam waist position between respective image heights, a multibeam optical scanning device of a novel construction which can carry out satisfactory image recording excellent in environmental resistance can be realized. In addition to the above effect, according to the invention as described in Claim 5, a multibeam optical scanning device which is greater in the number of beams and can carry out high-speed recording can be realized.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] A view showing a mode for carrying out the present invention, which is a perspective view showing a schematic construction of a multibeam optical scanning device.

[Fig. 2] An exploded perspective view showing a construction example of light source portions of a light source unit to be loaded into the multibeam optical scanning device as shown in Fig. 1.

[Fig. 3] An exploded perspective view showing another construction example of light source portions of a light source unit to be loaded into the multibeam optical scanning device as shown in Fig. 1.

[Fig. 4] An exploded perspective view showing a construction

example of light source portions of a light source unit to be loaded into the multibeam optical scanning device as shown in Fig. 1.

[Fig. 5] Views showing an embodiment of the present invention, which are explanatory views of a configuration of semiconductor lasers and coupling lenses when the light source unit as shown in Fig. 4 is used.

[Fig. 6] Views showing optical systems from light sources to a scanning surface and optical paths of light beams passing therethrough when a 2-beam light source unit is used in an extended manner on a plane in the main scanning direction, wherein (a) is an example where light beams from two semiconductor lasers do not intersect in the vicinity of a deflecting and reflecting surface of a deflector, and (b) is an example where light beams from two semiconductor lasers intersect in the main scanning direction in the vicinity of a deflecting and reflecting surface of a deflector.

[Fig. 7] Explanatory views of a curvature of field in an optical scanning device according to the present invention.

[Fig. 8] Explanatory diagrams of depth curves of the spot diameter in an optical scanning device according to the present invention.

[Fig. 9] A diagram showing an optical path of the chief ray

of light beams from a semiconductor laser and a height in the sub-scanning direction when the distance between the light source unit and deflector is 276mm and 776mm.

[Fig. 10] Views showing another embodiment of the present invention, which are explanatory views of a configuration of semiconductor lasers and coupling lenses when the light source unit as shown in Fig. 3 is used.

[Description of Symbols]

101, 102, 106, 107, 201, 202, 501, 502, 503, 504: Semiconductor laser

104, 105, 108, 109, 204, 205, 505, 506, 507, 508: Coupling lens

103, 103', 203, 509: Supporting member

111: Beam composing means (Beam composing prism)

400: Multibeam light source unit

401-1: First light source portion

401-2: Second light source portion

402: First optical system (Cylindrical lens)

403: Deflector (Polygon mirror)

404, 406: Second optical system

405: Turning mirror

407: Photosensitive body

407a: Scanning surface (Photosurface)

408: Synchronous detection mirror

409: Synchronous detection sensor

Fig.1

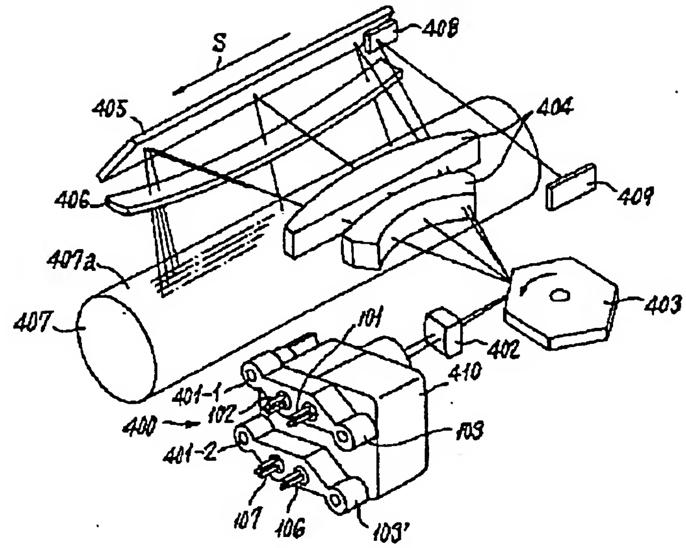


Fig.2

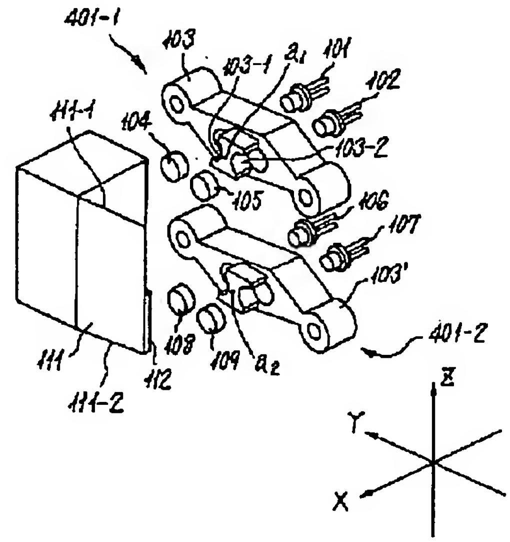


Fig.3

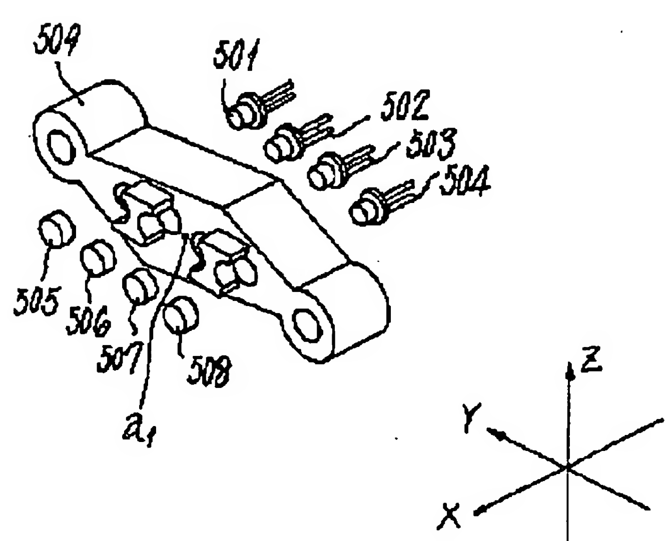


Fig.4

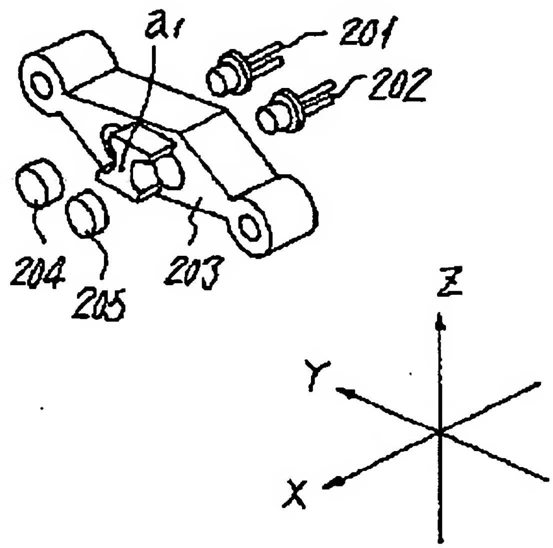


Fig.5

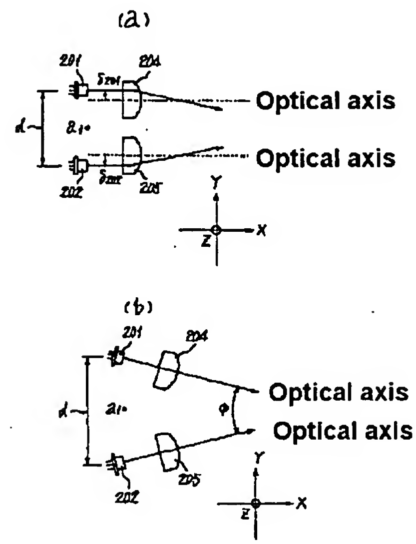


Fig.6

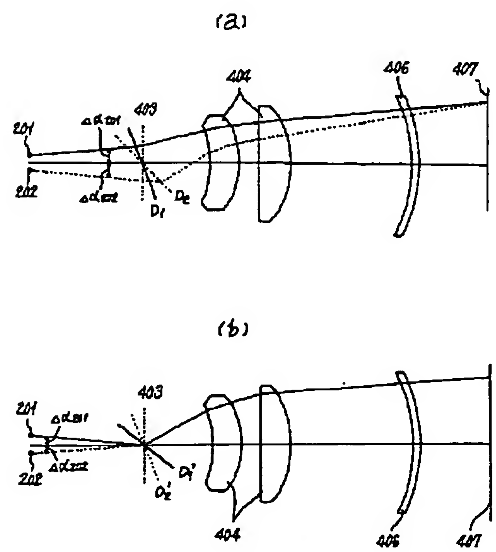


Fig.7

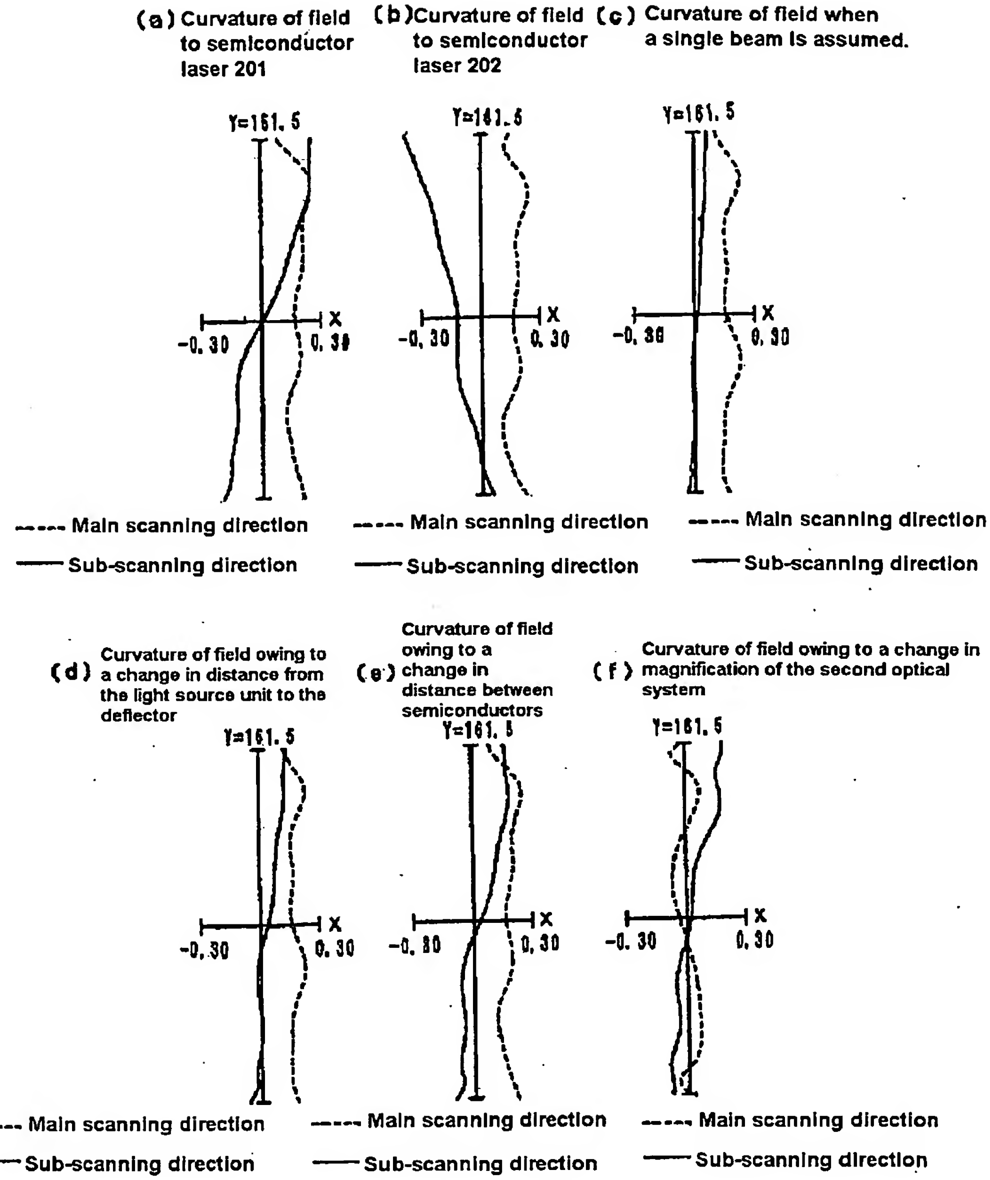
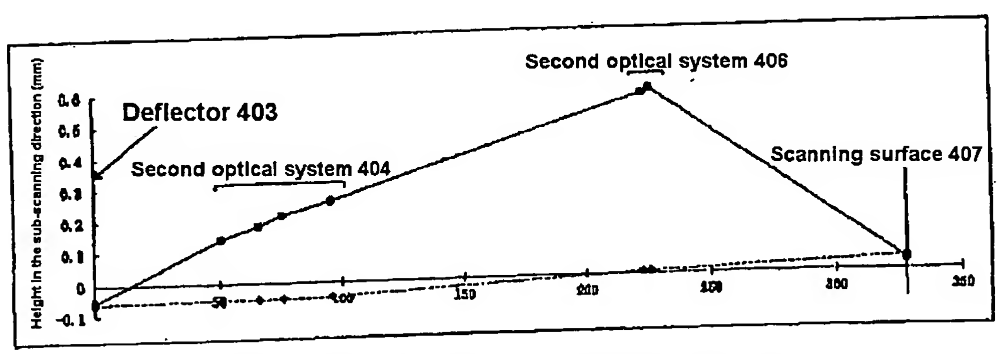


Fig.9

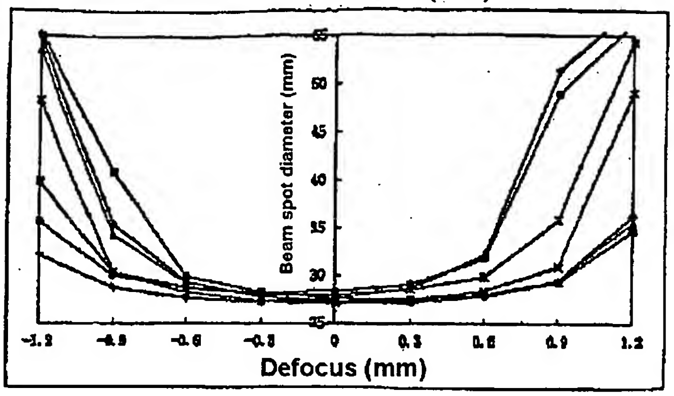


—— Optical path of the chief ray of light beams from the semiconductor laser 201 when the distance from the light source unit 400 to the deflector 403 is 276mm.

----- Optical path of the chief ray of light beams from the semiconductor laser 201 when the distance from the light source unit 400 to the deflector 403 is 776mm.

Fig.8

(a) Depth curves of the spot diameter of the semiconductor laser 201 (202)



(b) Depth curves of the spot diameter with a single beam

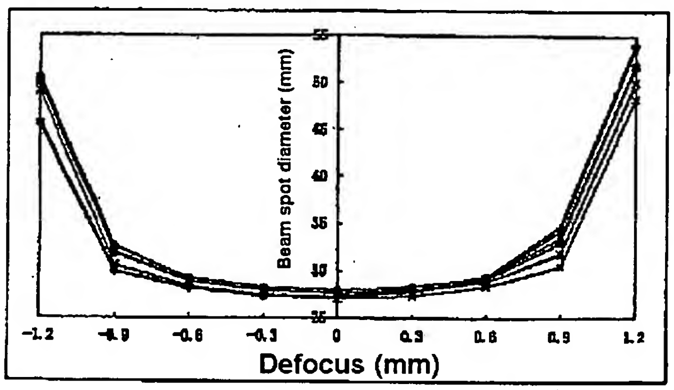


Fig.10